2. DTV SUSCEPTIBILITY TO GN INTERFERENCE

Results of the DTV susceptibility tests for GN interference are described in this section. It presents gating parameters, discusses relevant signal powers and DTV signal quality metrics, and provides *SER* and *BER* versus *INR* plots and INR_{TOV} and BER_{TOV} versus ζ plots.

2.1. Gating Parameters

Table 1 gives on-time, fractional on-time, and off-time (τ_{off}) gating parameters of the periodically gated-noise interference signals considered in the main body of this report. The set of gated-noise signals in Table 1 is denoted by the acronym GN, and each individual signal is specified by identifiers in the first column. An illustration of the gating parameters is given in Figure 1. Appendix A extends the scope of this experiment to GN(MB) interference signals, which are gated-noise signals that emulate MB-OFDM.

Table 1. GN Gating Parameters

GN	τ_{on} (μs)	τ_{off} (μs)	ζ
01	∞	0.00	1.0000
02	0.01	0.01	0.5000
03	0.01	0.03	0.2500
04	0.01	0.07	0.1250
05	0.01	0.15	0.0625
06	0.10	0.10	0.5000
07	0.10	0.30	0.2500
08	0.10	0.70	0.1250
09	0.10	1.50	0.0625
10	1.00	1.00	0.5000
11	1.00	3.00	0.2500
12	1.00	7.00	0.1250
13	1.00	15.00	0.0625
14	10.00	10.00	0.5000
15	10.00	30.00	0.2500
16	10.00	70.00	0.1250
17	10.00	150.00	0.0625

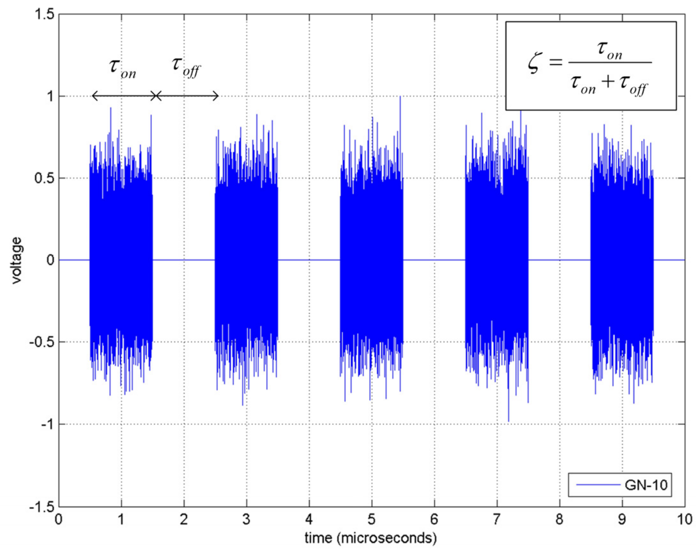

Figure 1. Simulated gated-noise signal, GN-10.

2.2. Signal Powers and DTV Signal Quality Metrics

Figure 2 illustrates reference points for the signal powers and DTV signal quality metrics acquired during the DTV susceptibility tests. *SNR* and *INR* define the average power of the DTV and interfering signals. These average power ratios were derived from vector signal analyzer data measured at IF and band-limited to B_{DTV} = 19.51 MHz in post-measurement processing by the same root-raised-cosine (RRC) filter found in the demodulator of the victim receiver. Figure B-1 provides a block diagram of the test hardware configuration and Section B.2 mathematically describes the power ratio measurements. DTV signal quality metrics *SER* and *BER* were acquired with the MPEG-2 transport stream monitor.[3] Section B.3 provides mathematical definitions of the DTV signal quality metrics.

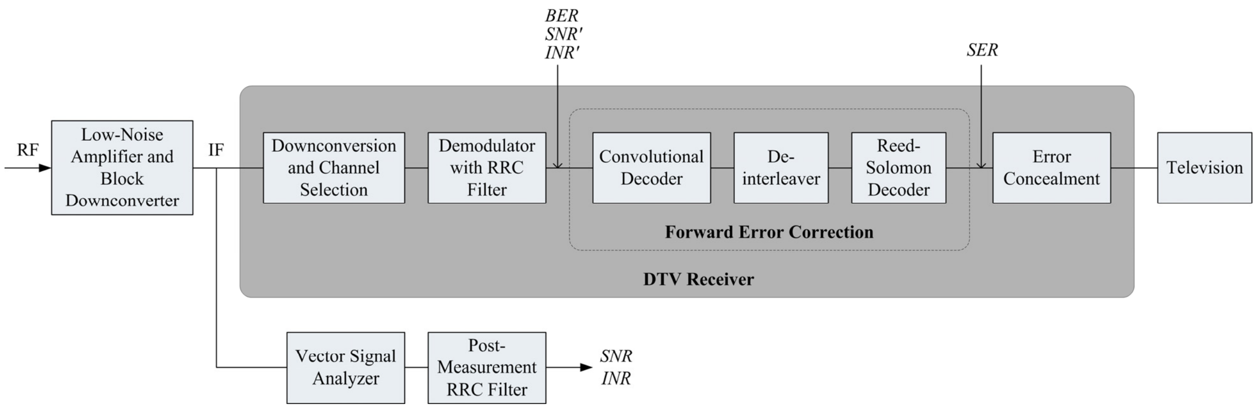

Figure 2. *SNR*, *SNR′*, *INR*, *INR′*, *BER*, and *SER* reference points.

It is important to note that *SNR* and *INR* were not measured at the same point as *BER*. Theoretical expressions for DTV signal quality metrics for Gaussian noise degradation are provided in Section B.4; these expressions use signal-to-noise ratio at the output of the demodulator (*SNR′*) as the dependent variable. Equation (B-1) was derived empirically to account for imperfect demodulation effects and compute *SNR′* from *SNR*. Using this model, *SNR′* = {8.2, 10.5, 12.5} dB was calculated from *SNR* = {9, 12, 15} dB. Note that this model was derived under Gaussian noise assumptions and cannot be generalized for gated-noise interference to obtain *INR′* from *INR* without further research. Therefore, test results are displayed as a function of the measurable dependent variables *SNR* and *INR*.

2.3. DTV Signal Quality as a Function of Interference Average Power

Figures 3 – 8 provide composite plots of measured *SER* and *BER* as a function of *INR* for *SNR* = {9, 12, 15} dB. Each page is dedicated to a single *SNR*, each plot is dedicated to a specific τ_{on}, and each curve represents a single ζ. Figures 3, 5, and 7 provide composite plots of *SER* while Figures 4, 6, and 8 provide composite plots of *BER*. The following are general comments regarding the shift, separation, and slope of these curves.

Both *SER* and *BER* shifted toward greater *INR* with increasing *SNR*. This occurred because more interference was needed to degrade stronger satellite signals.

[3] Modulation error ratio (*MER*) was also acquired with the MPEG-2 stream monitor. *MER* is an important DTV signal quality metric referenced to the output of the demodulator. Measured *MER*, however, was inconsistent with theory which prevented its use in this report.

SER curves with fixed *SNR* and τ_{on} show increased separation (from the continuous-noise case) with decreasing ζ. Likewise, all curves with fixed *SNR* and ζ exhibit increased separation with increasing τ_{on}. Hence, *SER* curves with τ_{on} = 10 ns and $\zeta \geq$ 0.25 lay close to the continuous-noise case, while those with τ_{on} = 10,000 ns and ζ = 0.0625 had the greatest separation. A notable anomaly to this trend occurred for GN-09 (τ_{on} = 100 ns, ζ = 0.0625), where the shallow slope of the *SER* curve caused it to cross higher-ζ *SER* curves.

SER curves were generally steeper than corresponding *BER* curves, which indicates that *SER* was more sensitive than *BER* to changes in average interference power. *SER* steepness was due to two stages of forward error correction (FEC), which were applied to post-Reed-Solomon segments but not to pre-Viterbi bits. Another trend was observed for sufficiently small ζ, i.e., ζ = 0.0625, where slopes of the *SER* curves were flatter compared to higher-ζ cases. This may be attributed to conditions more favorable to FEC performance or to longer off-times where errors were unlikely. In either case, DTV susceptibility to small-ζ gated-noise interference seemed to be more dependent on the temporal characteristics than on the power characteristics of the interference signal.

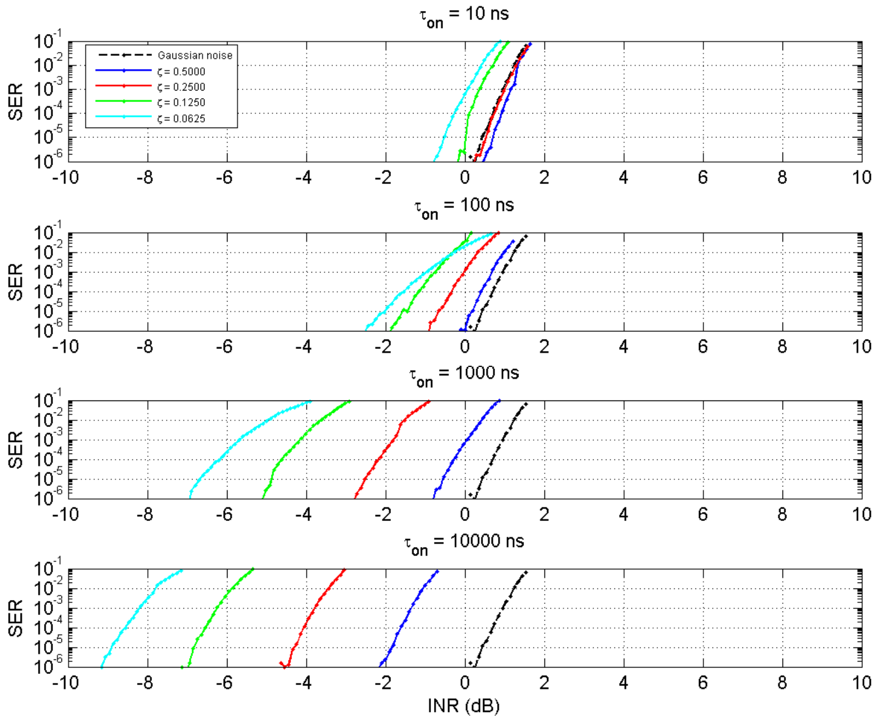

Figure 3. *SER* versus *INR* for a DTV receiver operating at *SNR* = 9 dB and exposed to GN interference.

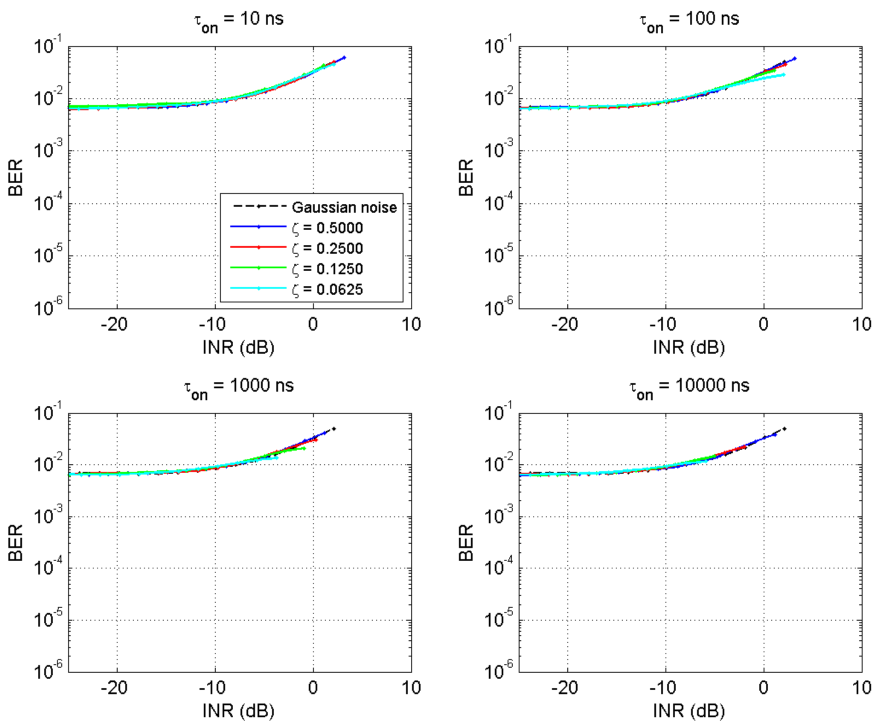

Figure 4. *BER* versus *INR* for a DTV receiver operating at *SNR* = 9 dB and exposed to GN interference.

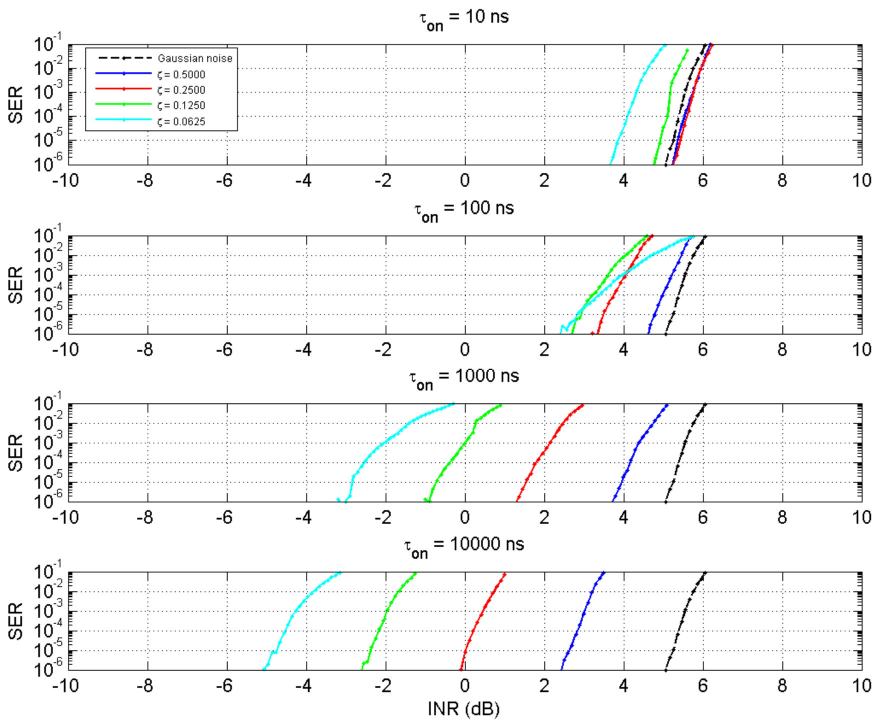

Figure 5. *SER* versus *INR* for a DTV receiver operating at *SNR* = 12 dB and exposed to GN interference.

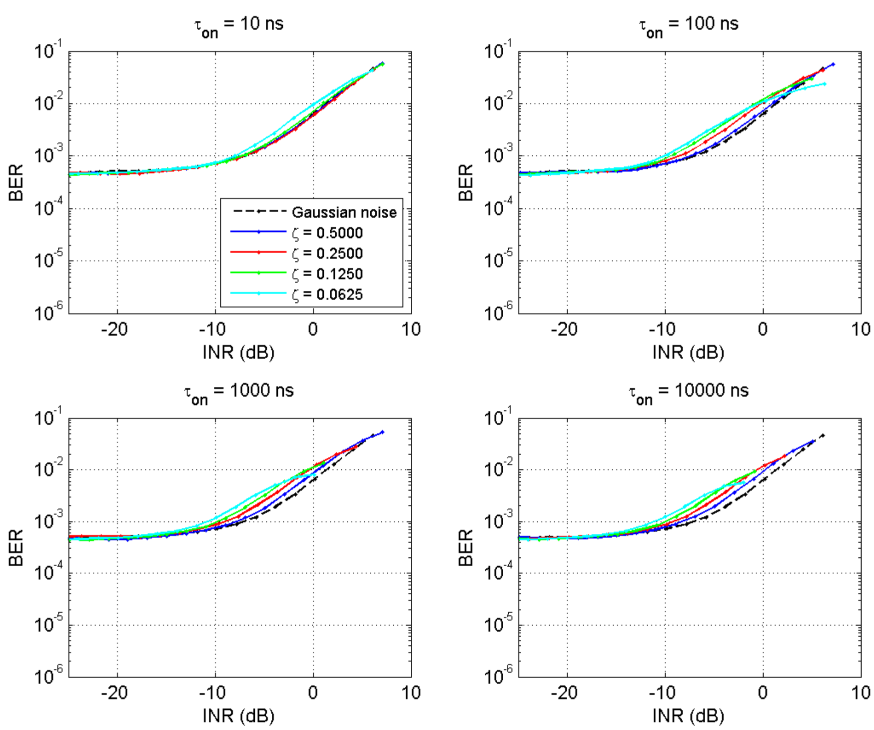

Figure 6. *BER* versus *INR* for a DTV receiver operating at *SNR* = 12 dB and exposed to GN interference.

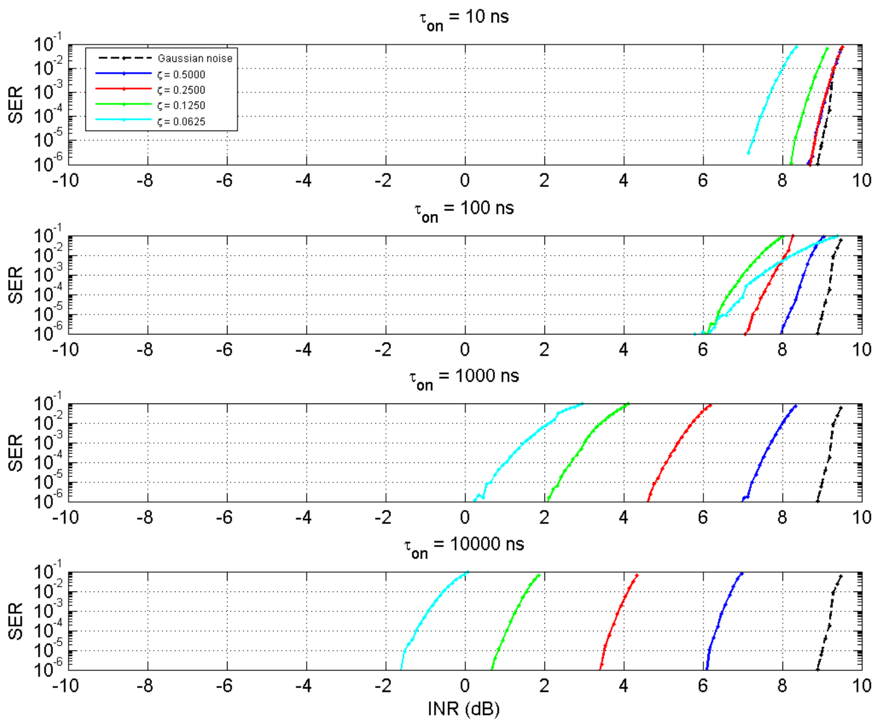

Figure 7. *SER* versus *INR* for a DTV receiver operating at *SNR* = 15 dB and exposed to GN interference.

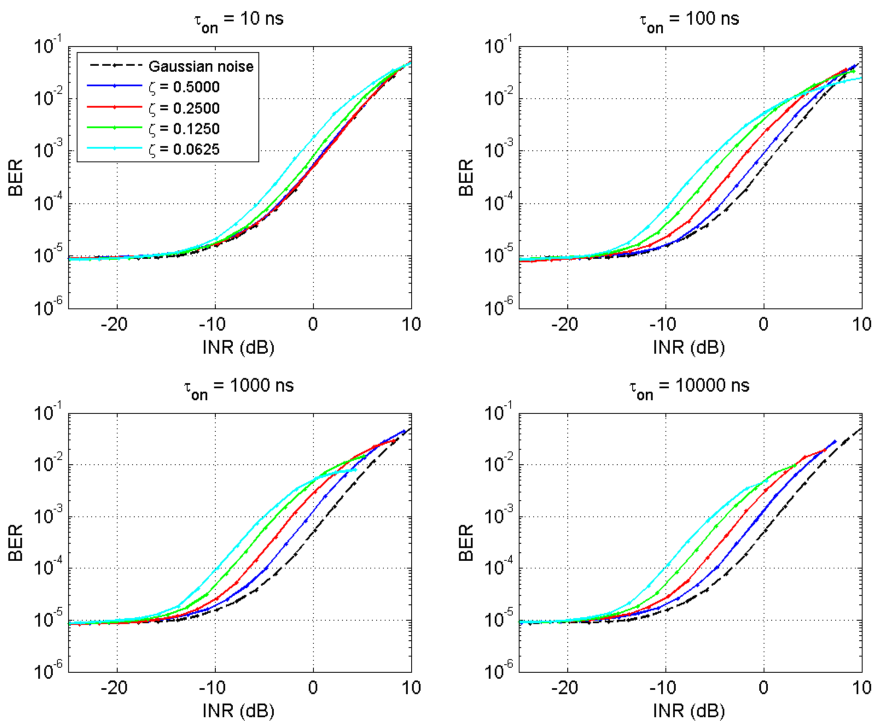

Figure 8. *BER* versus *INR* for a DTV receiver operating at *SNR* = 15 dB and exposed to GN interference.

2.4. DTV Susceptibility and FEC Performance as a Function of Interference Fractional On-Time

Figure 9 displays measured *SER* and *BER* curves for a DTV victim receiver operating at *SNR* = 15 dB and exposed to increasing levels of continuous-noise interference. This figure also identifies important DTV susceptibility and FEC performance metrics. Importantly, $SER_{TOV} = 10^{-4}$ is a level identified by video quality studies [7] as the threshold of visibility where video quality degradation is first evident.

INR that corresponds to SER_{TOV}, INR_{TOV}, is our primary DTV susceptibility metric. That is, receiver susceptibility increases as INR_{TOV} decreases. In Figure 9, INR_{TOV} is found vertically from the intersection of the measured *SER* curve and the SER_{TOV} horizontal line.

BER that corresponds to SER_{TOV}, BER_{TOV}, is our FEC performance metric. This metric quantifies the ability of the FEC to overcome bit errors caused by interference to achieve SER_{TOV}. In other words, larger BER_{TOV} indicates more corrected bits and better FEC performance. In Figure 9, BER_{TOV} is found horizontally from the intersection of INR_{TOV} and the measured *BER* curve.

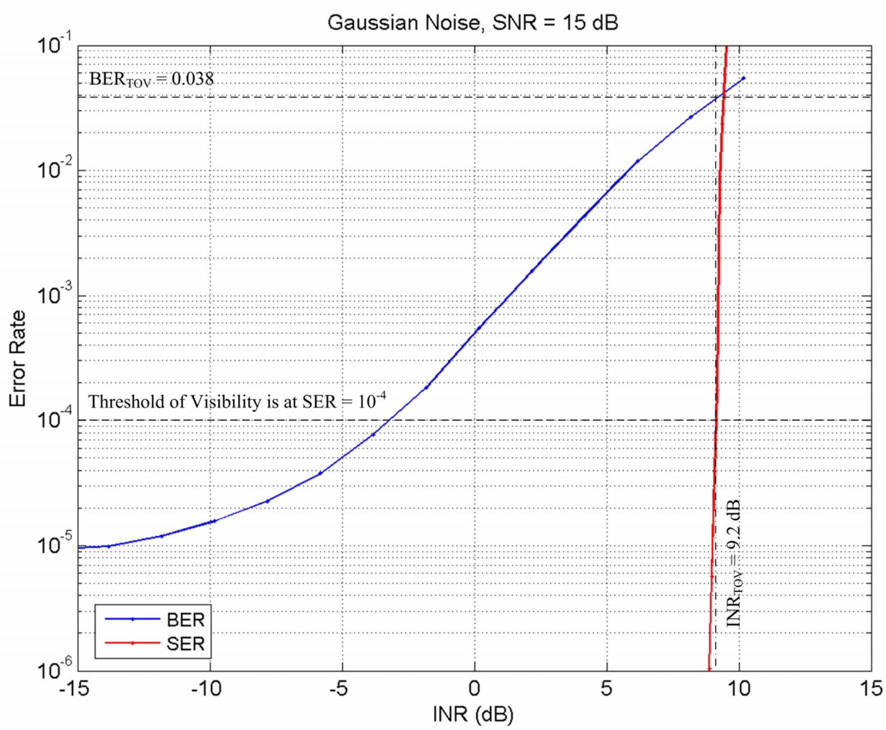

Figure 9. Illustration of threshold-of-visibility metrics.

Table 2 gives INR_{TOV} and BER_{TOV} metrics for all GN interference tests. A distinctive trend was the positive correlation between INR_{TOV} and BER_{TOV}. This demonstrates that DTV susceptibility was dependent on how effective the FEC was at overcoming bit errors caused by the interference. For example, the FEC was most effective at mitigating continuous-noise degradation and the receiver was least susceptible to continuous-noise interference.

Table 2. Measured DTV Susceptibility and FEC Performance for GN Interference

GN	Gating Parameters			SNR = 9 dB		SNR = 12 dB		SNR = 15 dB	
	τ_{on} (μs)	τ_{off} (μs)	ζ	INR_{TOV} (dB)	BER_{TOV}	INR_{TOV} (dB)	BER_{TOV}	INR_{TOV} (dB)	BER_{TOV}
01	∞	0.00	1.0000	0.7	0.038	5.4	0.038	9.2	0.038
02	0.01	0.01	0.5000	0.9	0.038	5.5	0.038	9.0	0.038
03	0.01	0.03	0.2500	0.7	0.038	5.6	0.038	9.0	0.038
04	0.01	0.07	0.1250	0.1	0.036	5.1	0.034	8.5	0.034
05	0.01	0.15	0.0625	-0.3	0.031	4.1	0.029	7.5	0.029
06	0.10	0.10	0.5000	0.4	0.035	5.0	0.033	8.4	0.033
07	0.10	0.30	0.2500	-0.3	0.030	3.8	0.028	7.5	0.028
08	0.10	0.70	0.1250	-1.2	0.025	3.2	0.023	6.7	0.023
09	0.10	1.50	0.0625	-1.5	0.021	3.4	0.018	7.0	0.018
10	1.00	1.00	0.5000	-0.3	0.032	4.2	0.030	7.5	0.030
11	1.00	3.00	0.2500	-2.2	0.022	1.8	0.018	5.1	0.018
12	1.00	7.00	0.1250	-4.6	0.015	-0.4	0.011	2.7	0.011
13	1.00	15.00	0.0625	-6.2	0.012	-2.5	0.007	1.1	0.007
14	10.00	10.00	0.5000	-1.6	0.025	2.8	0.022	6.3	0.022
15	10.00	30.00	0.2500	-4.1	0.017	0.2	0.012	3.7	0.012
16	10.00	70.00	0.1250	-6.5	0.013	-2.2	0.007	1.1	0.007
17	10.00	150.00	0.0625	-8.6	0.010	-4.5	0.004	-1.2	0.004

Figures 10 – 15 plot INR_{TOV} and BER_{TOV} as a function of $1/\zeta$ in dB, where $\zeta = \{1.00, 0.50, 0.25, 0.125, 0.0625\}$ correspond to $10\log(1/\zeta) = \{0.00, 3.01, 6.02, 9.03, 12.04\}$ dB. The horizontal dashed reference line in each INR_{TOV} plot corresponds to DTV susceptibility that is strictly dependent on average power of the interference signal. As an example, Figure 16 illustrates three gated-noise signals with different ζ but the same average power. If susceptibility were strictly dependent on average power, then the victim receiver would be equally susceptible to each of these signals.

For fixed SNR and τ_{on}, INR_{TOV} decreased (relative to the continuous-noise case) with decreasing ζ. Likewise, for fixed SNR and ζ, INR_{TOV} decreased with increasing τ_{on}. Hence, $INR_{TOV}(\tau_{on} = 10$ ns, $\zeta \geq 0.25)$ lay close to the horizontal reference line, while $INR_{TOV}(\tau_{on} = 10{,}000$ ns, $\zeta = 0.0625)$ deviated the furthest. A notable anomaly to this trend occurred when $INR_{TOV}(\tau_{on} = 100$ ns, $\zeta = 0.0625)$ was greater than $INR_{TOV}(\tau_{on} = 100$ ns, $\zeta = 0.125)$.

These observations demonstrate that DTV susceptibility was dependent on temporal parameters of the interfering signal, i.e., τ_{on} and τ_{off}. If τ_{off} was less than or comparable to the reciprocal bandwidth of the victim receiver RRC filter, i.e., approximately $1/B_{DTV} = 51.3$ ns, then INR_{TOV} clustered near the horizontal reference line and DTV susceptibility was strictly dependent on average power of the interference signal (independent of τ_{on} and ζ). However, if τ_{off} was significantly greater than the reciprocal bandwidth of the victim receiver, then DTV susceptibility was clearly dependent on τ_{on} and ζ.

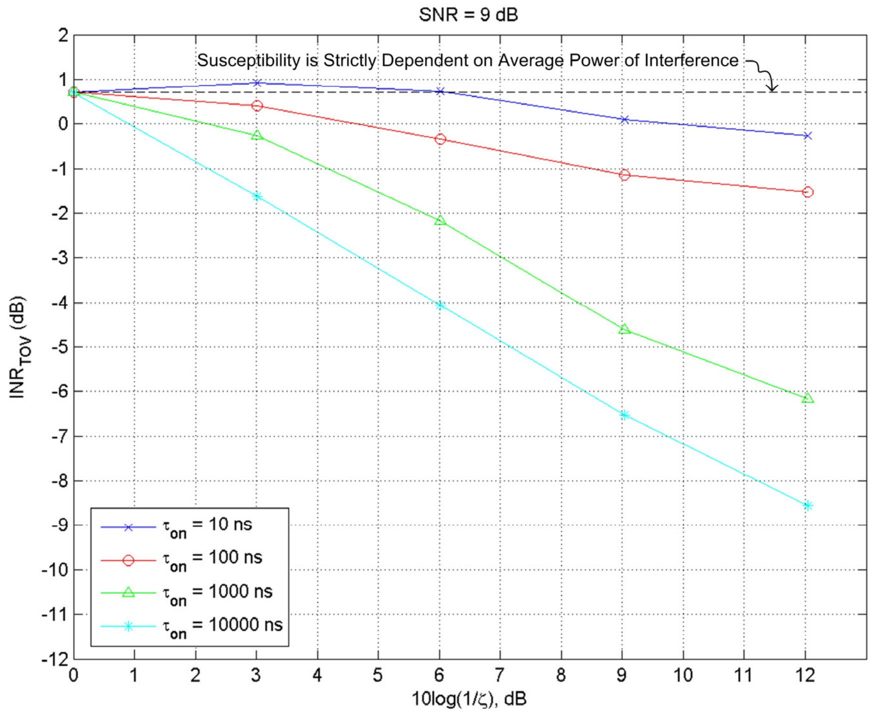

Figure 10. INR_{TOV} versus $10\log(1/\zeta)$ for a DTV receiver operating at SNR = 9 dB and exposed to GN interference.

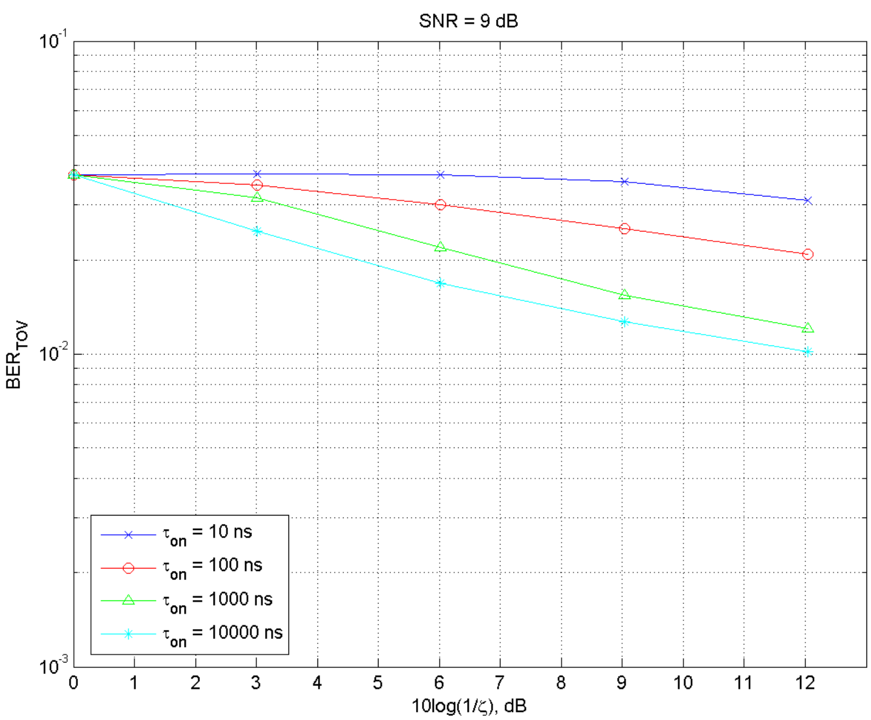

Figure 11. BER_{TOV} versus $10\log(1/\zeta)$ for a DTV receiver operating at SNR = 9 dB and exposed to GN interference.

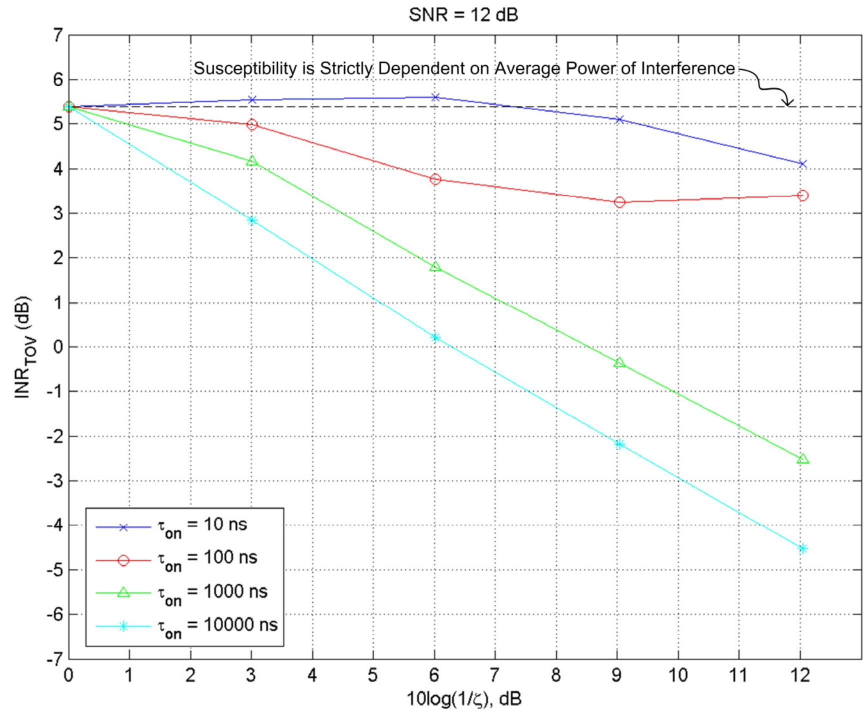

Figure 12. INR_{TOV} versus 10log(1/ζ) for a DTV receiver operating at SNR = 12 dB and exposed to GN interference.

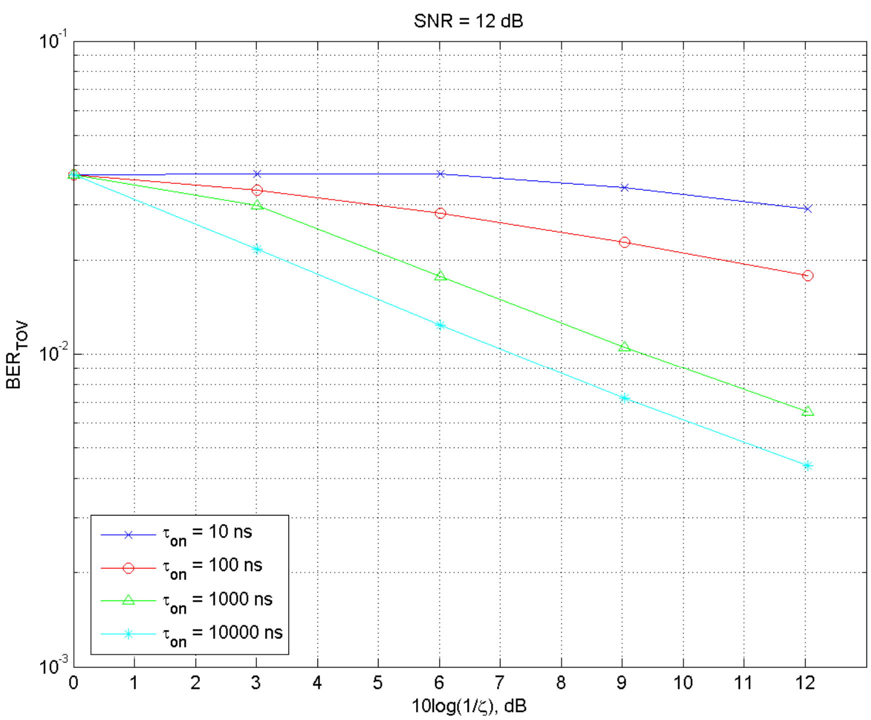

Figure 13. BER_{TOV} versus 10log(1/ζ) for a DTV receiver operating at SNR = 12 dB and exposed to GN interference.

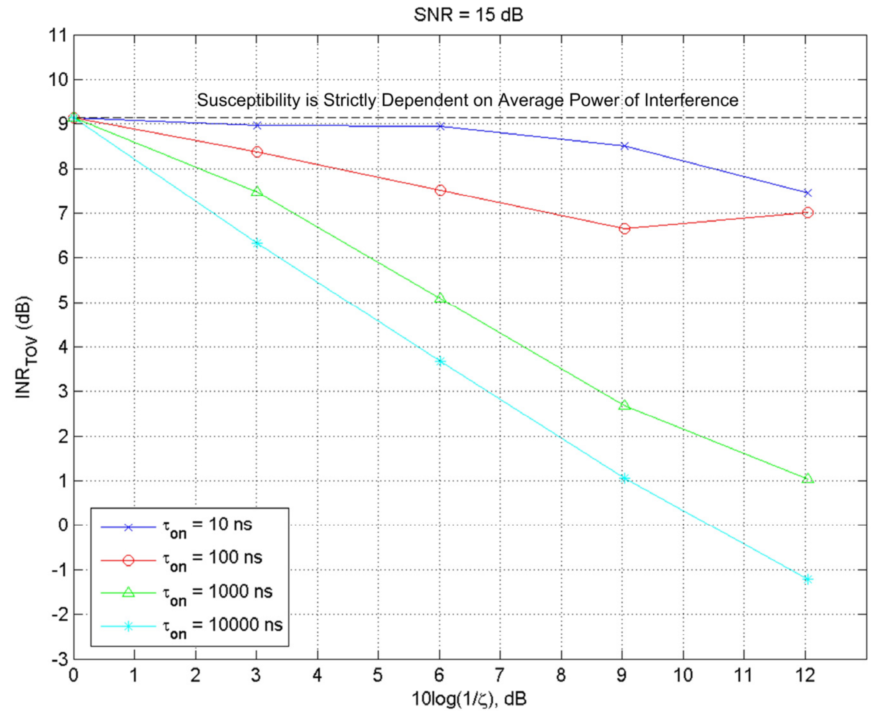

Figure 14. INR_{TOV} versus 10log(1/ζ) for a DTV receiver operating at SNR = 15 dB and exposed to GN interference.

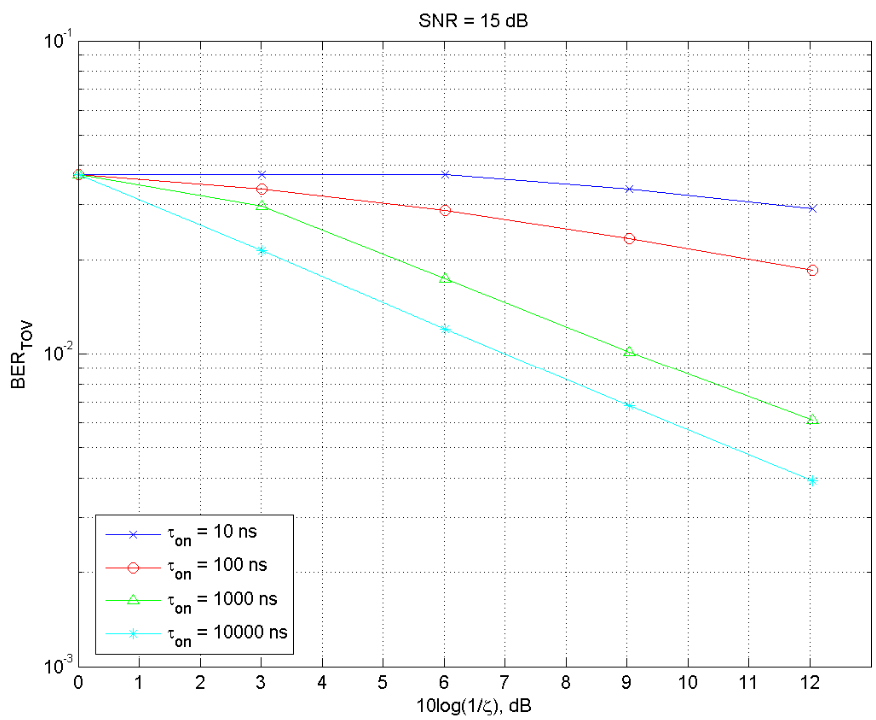

Figure 15. BER_{TOV} versus 10log(1/ζ) for a DTV receiver operating at SNR = 15 dB and exposed to GN interference.

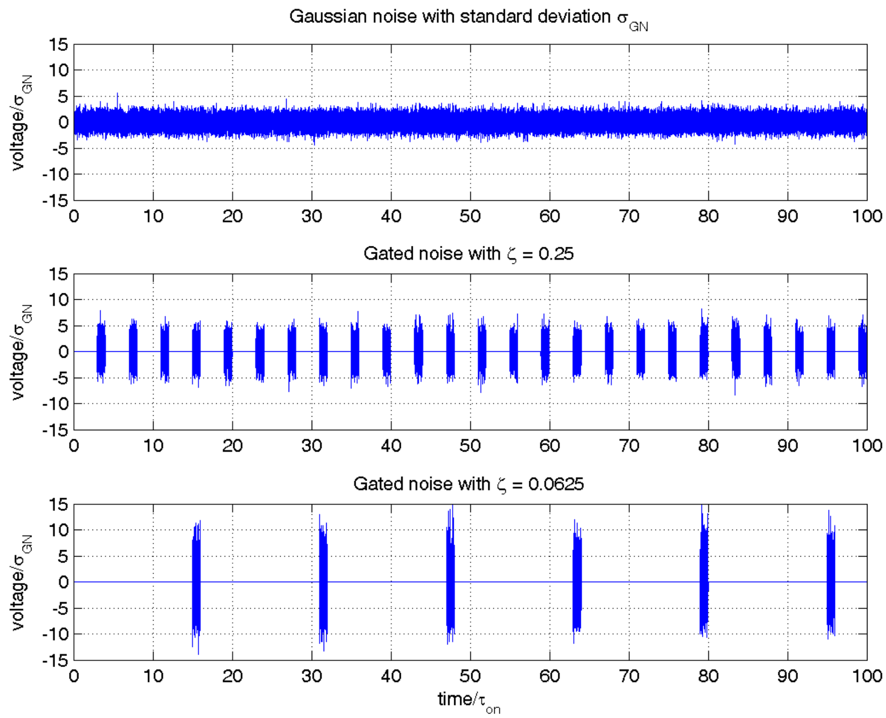

Figure 16. Simulated gated-noise signals with the same average power.